

the planet's history and is approximately marked in the Arcadia quadrangle by Mariotis Fossae, was subsequently covered by volcanic-related deposits, such as

Elevation control in the Arcadia quadrangle from Mariner 9 data is among the most questionable on the planet (Harold Masursky, oral commun. 1974). Available data (U.S. Geological Survey, 1976) suggest that Alba Patera stands as a vast, flat-topped mountain about 2 km above the adjacent plains and that the Tempe Plateau rises about 3 km above the adjacent plains. Average regional slopes along the edges of the plateau are about 0.5°, whereas the average slope across the 2-km north-south extent of the quadrangle is about 0.1°. The Arcadia quadrangle lies at the north termination of the Tharsis province of Mars (Carr, 1974), a 5,000-km-long bulge that reaches a crestal elevation of 11 km in the vicinity of Noctis Labyrinthus. The bulge is flanked by 27-km-high Olympus' Mons and by a northeast-trending line of major volcanoes consisting of Arsia Mons, Pavonis Mons, and Ascraeus Mons. On the projection of this line of major volcanoes, a prominent fault zone, Tempe Fossae, crosses the Tempe Plateau. The Tharsis bulge is characterized by a system of semiradial faults (Carr, 1974), which in the Arcadia quadrangle trends north to northeast as a series of magnificent scarps, some members splaying around the central core of Alba Patera. METHODS USED

The Arcadia quadrangle exhibits a particularly rich variety of geologic age relations because of the close juxtaposition of so many fundamental ancient cratered terrains, polar-related terrains, lunar-appearing plains, and the volcanic terrains of Tharsis. In addition, a number of widespread geometric patterns yield other sets of relative-age relations by their superposition and relative truncation. These include several major unconformities and fault systems, the radial channels of Alba Patera, regional systems of mare ridges, lines of topographic escarpments, channel and canyon encroachments, etch-pit patterns in volatile-rich deposits, and crater-density differences. All the above features were considered in constructing the geologic sequence, but emphasis was placed on crater-density measurements. Areas of apparently homogeneous crater density were outlined for all major map units and for all suitable Mariner B-camera imagery within and adjacent to the Arcadia quadrangle. For each area, a crater size-frequency curve was prepared; a standard size-frequency curve was then used to project these measurements to a 1-km intersection. as described by Neukum and Wise (1976a, b). Where "survivor" craters (craters visible beneath a younger cover) produce a well-defined break in the frequencydistribution curves, intersections for both the older substrate and younger cover are read. The values determined at these intersections, namely, the cumulative number of craters greater than 1 km in diameter per 106 km², are given as craterdensity numbers in the description of map units. This crater-density scale provides a relative time frame for discussion of the geology of the quadrangle. A proposed absolute time scale derived from lunar crater data, as described by Neukum and Wise (1976a, b), is also included. For these purposes, it is unfortunate that the quality of Mariner 9 imagery is so limited throughout much of this critical quadrangle. A number of age relations are too complex to be uniquely soluble from Mariner 9 imagery and will undoubtedly be revised with Viking

GEOLOGIC SUMMARY Major geologic events and their time relations to map units and cratering scale are indicated in the graphic legend. Highlights of this historical sequence from oldest to youngest are: (1) formation and cratering of the intensely cratered upland material (crater density 100,000; 4.4 b.y.), (2) development of the boundary, now buried in the Mareotis Fossae area, between the heavily cratered and lightly cratered hemispheres of Mars; (3) extrusion of the Lunae Planum material, formation of the fractured upland material of the Tempe Plateau, and formation of the northern region of the fractured cratered plains material (crater density 15,000-20,000; 4.1 b.y.); (4) disruption of the Tempe Plateau deposits by major faulting (crater density 10,000-15,000; 4 b.y.), (5) deposition of the frost-rich etched upland material onto the Tempe Plateau, and deposition of similar materern region; burial of the south edge of the plateau by the older cratered plains material (crater density 5,000-10,000; 3.9-4 b.y.); (6) major dissection of the west edge of the plateau; valley-wall erosion along Kasei Vallis (crater density 2,500-5,000; 3.7-3.8 b.y.); (7) construction of the Alba Patera and its associated plains (crater density 1,000-2,300; 3.4-3.7 b.y.; distal parts of western aureole range as great as 5,000; 3.9 b.y.), (8) development of the splaying fault system of Alba Patera (crater density 500-1,000; 3-3.5 b.y.), and (9) formation of young dunes, eolian plains deposits, and thermokarst features.

to that of Lunae Planum material (unit pl). Subdued traces of Alba fracture system visible locally. Interpretation: Composition uncertain; possible extension of Lunae Planum volcanic rocks. Occurence of 50- to 60-km-diameter craters in 53°-55° N. latitude belt may indicate intensely cratered-upland material (unit uic) near surface. Type locality: Lat 60°N., long 100°W. LUNAE PLANUM MATERIAL-Covers Tempe Plateau in southeastern part of quadrangle; moderately cratered (crater density 18,000-20,000), with some remarkably fresh 25-km-diameter craters. North-northwest-trending mare-type ridges oriented similarly to those of Lunae Planum. Fracture traces rare and subdued. *Interpretation*: Volcanic lava flows of probable basaltic composition, with compressional mare-type ridges. May be related to radial-flow center of radial etched-mountain material (unit mre) at lat 44.7° N., long 61.5° W., with frost cover overlying it and some nearby deposits. Type locality: Lat 35°N., long 61°W.; A-frame DAS 8731004 OTHER MATERIALS ARK MATERIAL-Occurs as low-albedo patches on crater floors and in deep valleys or lee areas of northern Tempe Plateau. Patterns change slightly with time. Interpretation: Dune deposits, some presently active. Type locality Lat 50.5° N., long 69° W.; B-frame DAS 12993018 ETCHED-DEPRESSION MATERIAL—Occurs on flat floors of irregular depressions in Tempe Plateau. Commonly of

CHANNEL MATERIAL-Occurs in extreme southeast corner of quadrangle along floor of Kasei Vallis; marked by streamlined landforms and winding linear depressions leading downward to Acidalia Planitia to northeast. Floor deposits of canyons with patterns of giant muderacks also mapped with this unit. *Interpretation*: Alluvial deposits of former streams. Type locality: Lat 30° N., long 60° W. RIBBED-PIEDMONT MATERIAL-Forms lowland terrace at foot of erosional scarps in Kasei Vallis in southeastern par of quadrangle in MC-10; lightly cratered: density of 5000 obtained in MC-10. Delicate ribbed texture described in MC-10 (Milton, 1975), unresolvable in MC-3. Interpretation: Thin deposits on pedimentlike surface encroaching northwestward. Older fractures etched into delicate ribbed pattern. Localization follows uplift, warping, and major faulting of Tempe Plateau and its burial by oldest deposits of cratered-plains material (unit pc). Surface subsequently incised at southeast edge of channel material (unit ch).

irregular shape but with elongations or alinements parallel

to regional fractures; queried where the depressions may be

fault troughs. *Interpretation:* Residue on floors of ther-

mokarst depressions created by local degradation of volatile-

B-frame DAS 08587049

rich deposits. Type locality: Lat 38.5°N., long 86°W.;

MATERIALS

MATERIALS

EVENTS

Alba building

plateau

Polar and upland

Main Tempe

hemispheres

tense cratering

o southern part of Tempe Plateau; some mottling and

subdued fracture traces visible; no reliable crater counts.

Interpretation: Composition uncertain, possibly volcanic

ash and eolian deposits. Immediately predates Alba events

but deposited unconformably across major fractures of

Tempe Plateau. Unit is thin and possibly lower facies of

cratered-plains material (unit pc). Type locality: Lat

MOTTLED AND STREAKED-PLAINS MATERIAL-Occurs

in northeast corner of quadrangle; low albedo; moderate

density (9,000) of 10-km-diameter craters. Pedestal craters

and wind streaking common. *Interpretation*: Volatile-rich

high-latitude deposit overlying high-albedo plains material

(unit pha). Surficial eolian deposits cause much of streak-

ing. Removal of volatiles such as water or solid-CO2 ice

caused active retreat of south and west edges. Surface

removal of these volatiles except where protected by crater

aprons has produced pedestal craters. Type locality:

eastern part of quadrangle adjacent to mottled and streaked-

deposit similar to mottled and streaked-plain material; but

higher volatile content and increased albedo. Presently

being degraded by northeast-receding scarp edge at lat

61°N., long 85°W. Conformably underlies mottled and

streaked-plains material and unconformably overlies

cratered and fractured-plains material (unit pcf). Type

curs in northern and northwestern parts of quadrangle;

intermediate albedo; crater density (18,000) comparable

CRATERED AND FRACTURED-PLAINS MATERIAL-Oc-

locality: Lat 68° N., long 85° W.

plains material (unit pms); of comparable crater density.

HIGH-ALBEDO PLAINS MATERIALS-Occurs in north-

Lat 58° N., long 62° W.; A-frame DAS 11835991

36° N., long 75° W.

Early crust and in

Type locality: Lat 30° N., long 63° W. CRATER MATERIALS Craters are classified according to morphological characteristics. Within given size range, sequence implies age order, but classes indicate differing ages with differing sizes, as indicated on graphic legend. Craters less than 10 km in diameter are not mapped. Most craters are believed to be of impact MATERIAL OF VERY SHARP RIMMED CRATERS-Rims complete, bowl very deep and steep sided MATERIAL OF SHARP RIMMED CRATERS-Rims complete and rough looking where diameter exceeds 30 km;

floors are shallow bowls MATERIAL OF SUBDUED CRATERS-Rims complete but subdued, floors flat but somewhat lower than adjacent MATERIAL OF HIGHLY DEGRADED CRATERS-Rims very subdued or incomplete, floors flat and about same elevation as adjacent terrain PEDESTAL CRATERS-Similar to c3 craters but with apron standing above level of surrounding terrain. Interpretation: Erosional remnant where crater apron has protected under lying substrate. Substrate may be volatile rich in this area EXHUMED CRATERS-Similar to c2 craters but exhumed by

B-frame DAS 11835606

Contact—Queried where extrapolated on basis of albedo or uncertain topographic criteria Fresh fault scarps and fault-line scarps—Sharply edged and commonly irregular, following older fractures for short distances. Line marks face of scarp; hachures on downthrown side or on alternate sides for very narrow graben Fault-line scarps of intermediate degrees of sharpness—Result from age, erosion, or moderate degrees of burial. Hachures on downthrown side or on alternate sides for very narrow

removal of cover. Type locality: Lat 49°N., long 81.3°W.;

T. T. Very subdued fault-line scarps-Result from age or deep burial or both. Hachures on alternate sides of narrow Faint fracture traces and subtle fracture-related photolinears

Large, extremely subdued, troughlike linears O-O-O Young, sharply defined crater chains

o--o--o Crater chain with very subdued topographic expression

Remnant or buried crater rim crest

Wind streaks of low albedo Radiating channels of probable volcanic origin at Alba Patera and sinuous channels of unknown origin in other areas. Double headed where slope direction uncertain or where

localized on projection of mare ridges Ridge lines of probable volcanic origin

Irregular closed depressions of probable collapse origin Crater rim crest-Not shown around smaller craters or where indistinct; used as contact in places

INTRODUCTION The Arcadia quadrangle of Mars contains three distinct geologic provinces: (1) the 1000-km-diameter shield volcano of Alba Patera, which occupies the southwestern quadrant; (2) the complex Tempe province, which comprises a number of younger volcanic and sedimentary blanket deposits over an ancient, highly cratered crust forming a plateau in the southeastern quadrant; and (3) a plains province, consisting of northern wind-swept, cratered plains and some younger subpolar deposits in the northeast corner of the quadrangle, plus less cratered plains surrounding much of the Tempe and Alba regions. The plateau, informally named the Tempe Plateau and part of the proposed formal term Tempe Terra is separated from the main regions of cratered martian highlands to the south by Kasei Vallis, appearing at the extreme southeast corner of the map, which slopes northeastward onto Chryse Planitia. The boundary between the plateau terrain and the northern plains is part of a planetwide distinction between a heavily cratered southern and equatorial hemisphere averaging 3 to 5 km in elevation, and a more lightly cratered northern region averaging -2 to -3 km in elevation. This boundary, which formed early in

the fractured uplands material, and by deposits rich in water and carbon dioxide ice, such as the etched upland material. Volatilization and slumping of these younger terrains constituted a second local cycle of modification of the boundary. Eastward retreat of the plateau edge during this cycle left behind the present complex zone, as wide as 250 km, of embayments and mesas forming the west

Tempe Plateau Province The cratered upland material or its degraded hilly equivalent forms the basement of the plateau, cropping out along its erosional escarpment and in part of its north-central interior. Remnants of craters as large as 125 km in diameter are visible locally within this terrain. Unconformably overlying the basement in places is a sheet of the Lunae Planum material, probably consisting of basaltic lava flows, as judged by the striking similarity of its ridges to those on lunar maria. A center of radial-flow patterns at lat 44.3°N., long 61.5°W., merging with the Lunae Planum pattern of mare-type ridges, is probably the volcanic source for some of these flows. Other upland deposits of similar age, including the fractured upland and mottled upland materials, cover much of the rest of the plateau. They are probably lavas similar to the Lunae Planum deposits but show no clear mare-type ridges in the available imagery; a possible flow front is visible in B-frame DAS 08731039 (lat 39° N., long 68° W.). These older upland deposits bury the more ancient boundary between the heavily and lightly cratered hemispheres of Mars. Locally they are intensely faulted by the Tempe Fossae system, although faulting is not a necessary criterion for identification of the terrain. The western and northern parts of the plateau, as well as the area just west, are locally blanketed by deposits of late or post-Tempe fault age, which commonly weather to closed depressions or etch pits. The pits are interpreted as thermokarst depressions that would indicate high frost-content in these deposits. Their occurrence in a sparsely cratered, smooth terrain is a major criterion for defining the etched upland material. Gatto and Anderson (1975) point out a remarkable similarity between the degrading deposits in one picture of the radially etched mountain (B-frame DAS 08731179, lat 44.3°N., long 61.5°W.) and some terrestrial thermokarst topography. A thin cover of frost deposits is the probable cause of the nearly complete absence of any fresh craters in the intense ly cratered upland material. This line marking the south limit of major depletion of small, fresh craters corresponds to that suggested by Soderblom and others (1973) and also approximately marks the south limit of thermokarst depressions. From the east map border, the line begins at about lat 38° N., follows northwestward along the south boundary of the intensely cratered upland material, and curves southwestward along the east edge of the etched upland material. Map-unit identification for the small, partly degraded, partly buried mountains in the west border region of the plateau is particularly troublesome. Some areas of hilly plains are closely associated with large craters typical of the intensely cratered upland material. Where large crater rims of this terrain and similarappearing masses project through unconformable cover (lat 35°N., long 91°W.), all are mapped with the hilly and cratered material. Some of these masses may be of the Lunae Planum material, but these subtle distinctions are impossible at

pitted areas of the etched upland material in the adjacent plateau, and so they are mapped as part of that terrain. Real distinctions probably exist within these units in that some remnants appear to include a very resistant, cliff-forming upper member (for example, the monkey-wrench-shaped area at lat 40° N., long 91° W.), whereas others exhibit a much less resistant lithology. With higher resolution imagery, an interesting chapter in stratigraphic detail may well be written for The single exception to lumping of these isolated masses into large, simple terrains is an array of similar-appearing, parallel ridges (the elongate ridge material), which are discussed below. Where isolated masses become too small for separate resolution or mapping, the knobby terrain or hilly piedmont material is ndicated. Deposits forming the knobby terrain material appear (B-frame DAS 09989923) as degraded, isolated, small bedrock knobs and mesas, whereas those of the hilly piedmont material seem more smoothly rolling and mottled, as might be expected from the more complete breakdown of their less resistant rocks. Thin facies (the cratered mottled plains material) of the cratered plains material partly cover older fault scarps, which further complicates the stratigraphy of the southern Tempe Plateau. Another facies problem of the southern plateau is the mottled upland material (lat 35° N., long 70° W.), characterized by distinct albedo

present resolution. In like manner, many isolated plateau remnants from lat

35° to 45°N. have the elongated, fracture-controlled, etchlike characteristics of

patches and the occurrence of troughs or sinuous channels subparallel to maretype ridges of the Lunae Planum material, to which this unit is correlated. Alba Patera Province A concentric distribution of lightly cratered terrains exhibiting radial channel patterns marks this volcanic province. Carr (1974) interpreted Alba as one of the oldest Tharsis volcanoes. Crater density in the central part of the cone is 2,100, whereas values on the aureole range from 1,000 to 5,000, which suggests that construction spanned about 400 m.y., in the time period 3.9 to 3.5 b.y. Much of the aureole is broken by a splaying fault system and chains of craters; nowhere in Mariner 9 imagery are flows younger than faults visible. The structure is broad and flat, with long lava-flow channels of possible basaltic composition. An outer limit of visible radial channels forms the approximate boundary drawn for the aureole. Exceptions occur at lat 32° N., long 118.5° W., where a lava-flow front forms the boundary, and in the northeastern quadrant, where imagery is too poor to resolve channels and only an extrapolated concentric boundary is mapped. With improved Viking imagery, aureole limits are likely extendable into some of the adjacent plains. Several larger possible survivor craters project through the aureole, which suggests a relatively thin cover. These craters seem absent in the central part of the cone, indicating much thicker burial. The central cone shows the same radial-channel pattern as the aureole, including some channels that pass through the boundary. This boundary is marked by the relative absence of younger faults and may more fully represent strength differences at depth than

is crowned by a central caldera complex and a few small, late-stage volcanic cones. Plains Provinces A large part of the northern third of the quadrangle is covered by the cratered and fractured plains material, having crater densities comparable to those of the Lunae Planum material. Thickness of the terrain is uncertain, but partly buried 50- to 60-km-diameter craters in the 53° to 55°-N.-latitude belt indicate a shalof younger sparsely cratered plains material overlies the older plains material on either side of its northwest-trending zone of outcrop. Contact zones, which are thin, many poorly defined, and possibly gradational, are commonly mapped at topographic boundaries but in some areas are placed where breaks in the pattern of craters, fractures, or albedo occur. Some of these surficial characteristics may be due to irregular distribution of haze and dust in the Mariner imagery and require revision with improved imagery. The plains material just west of the Tempe Plateau may in part be an extension of the Alba aureole material, or a degraded surface analogous to the degraded

hilly piedmont material at the foot of the Tempe Plateau and similar in composi-

surface lithologic differences. Like many other Tharsis volcanoes, Alba Patera

tion to the fractured upland material of the plateau. A distinctive mudcracklike n both quadrangles and probably correlates with Carr's unit. UNITS CONTAINING VOLATILES

fracture pattern in the cratered plains material near the southeast corner of the quadrangle is similar to that of a unit mapped by Carr (1975) in the adjacent harsis quadrangle. This material overlies the intensely fractured upland material Indications of the presence of such volatile-rich matter as water-ice, solid carbon dioxide, or clathrates are found in a number of units. Very large aqueous or aqueouslike channels occur only in the extreme southeast corner of the quadrangle as part of Kasei Vallis; details of this valley are better observed in adjacent

Within the Arcadia quadrangle the distribution of etched depressions is interreted as thermokarst topography associated with a volatile-rich cap on deposits covering the northern and western Tempe Plateau, as described above. The nature f this topography is best illustrated at lat 38°N., long 85°W. (B-frame DAS 08587049), where a series of closed depressions occurs on successively lower levels. Higher depressions are more equidimensional; lower ones tend to be more nterconnected and to form incipient drainage areas off the plateau edge near lat 38°N., long 85°W. The depression scarps appear to have been active only once and then to have become inactive as newer, deeper depressions formed, partly at the expense of the older ones. The floor levels of these successive flat-bottomed depressions may have been controlled by stratigraphy or formed by rapid horiontal erosion and volatilization at the level of some ancient fluid or groundwater table. With deeper erosion and drop in elevation of the surface of this luid table, active floor and scarp cutting ceased at this level and moved to a new, deeper level, creating successive scarped depressions. The absence of debris or of any evidence of wind action in the depressions argues for the removal of eroded olumes by volatilization or ablation

The two younger northeastern plains terrains, the high-albedo plains and the nottled and streaked plains materials, may also be largely composed of volatiles. hese terrains contain the quadrangle's only recognized pedestal craters, which are interpreted as the armoring of volatile-rich material by a crater apron and the subsequent erosion of unprotected surrounding areas. Contacts of each of these two terrains with underlying rock are presently migrating northeastward; the most long 87°W. (B-frame DAS 11658925). The deposits of these two terrains could be poorly consolidated sedimentary rocks, but their location as parts of a boreal deposit, their proximity to and possible gradation into the volatile-rich terrains capping the Tempe Plateau, and their similar crater density to the plateau terrains makes the volatile interpretation seem preferable. The high-albedo plains material would presumably be richer in volatiles. All exposures in the Arcadia quadrangle of deposits containing volatiles, with the exception of the intensely cratered upland material, show crater densities of from 2,000 to 9,000, with most numbers near 4,000 to 5,000 (3.7-3.8 b.y. This value is comparable to those measured on martian channels by Malin (1976), a time just subsequent to the first evidence of Tharsis fracturing in the quadrangle. These deposits may represent either a major episode of planetary degassing triggered by mantle activity in the Tharsis dome, or a recondensation of volatiles caused by Tharsis heating of ground ice trapped in deposits of terrains correlated

with the intensely cratered upland material, in this area or in other areas of the The volatile-rich cap of the western Tempe Plateau formerly extended for at least 250 km west of the present plateau edge, where isolated remnants indicate that it may have had a thickness of 1/2 km or more. The cap lies above and thickens westward across the plateau edge of Mareotis Fossae, which is the approximate buried ancient boundary between the heavily and lightly cratered hemispheres of Mars. This relation suggests that large quantities of volatiles moving eastward through the subpolar region were trapped by surface features of this ancient boundary. Thinner coverings of volatiles frost surfaces of the north half of the plateau and thicken northward into polar deposits at the northeast corner of the quadrangle. Depletion of the supply of abundant volatiles moving across the area, at a time represented by a crater density of 4,000 to 5,000, terminated the depositional phase and initiated the present cycle of ablation accompanied by the retreat of the west edge of the plateau and the northeastward retreat of the contact of the high-albedo plains material with the streaked and mottled plains materials in the northeast corner of the quadrangle. STRUCTURAL GEOLOGY Fault systems in the Arcadia quadrangle, which are among the most impressive

on Mars, form parallel arrays of horst and graben structures whose individual members range from 1 to 10 km in width and as much as 200 km in length. In the vicinity of the Alba aureole, these same fracture systems are marked locally by chains of endogenic craters. Relative ages of fractures were distinguished on the basis of freshness, crosscutting relations, sedimentary overlap, and crustal anisotropy effects of older ractures on younger ones. These relative age distinctions have validity within local areas but do not necessarily correlate across the entire map. Two main stages of faulting appear: (1) An older set of faults along Tempe Fossae, which seems to lie axial to the Tempe Plateau, predates the adjacent cratered plains; its crater density is between 10,000 and 15,000 (4.0-4.1 b.y.). (2) A younger set of faults, associated with the aureole of Alba Patera, splays around the volcano in an eastern branch, Tantalus Fossae, and a western branch, Alba Fossae; these Alba fractures postdate the radial channels, the youngest of which exhibit crater-A pattern of faults splaying around the central zone of Alba Patera could arise from regional extension of, combined with radial stresses on, the crustal load

of a volcanic pile (Wise, 1975). For Alba Patera the observed pattern would require viscous flow of the underlying mantle together with at least 5 km of relief on a sharp central cone, a geometric condition seemingly beyond the limits imposed by Mariner 9 elevation control. A preferable cause for the splaying fault pattern is strength anisotropy in crust undergoing regional extension. A solidified pluton that formerly fed the volcano could be strong enough to deflect faults around itself, protecting itself and its volcanic cover from significant breakup. This interpretation, drawn into the cross-section below, is in accord with existing elevation data, with the uniformity of radial-flow patterns across the boundary of entral cone and aureole, and with timing of faulting to postdate nearly all lava lows. These faults may also have been partly buried by very late stages of extruion of the central crater and cratered mountain materials. The fault systems of the Arcadia quadrangle, as parts of the semiradial fault system of the Tharsis province, should exhibit a stress structure related to doming n the province. The analogy of this fault pattern to May's (1970) pattern of Mesozoic dikes and stress trajectories around an opening Atlantic rift suggests a radial orientation of the sigma 1-sigma 2 plane and a concentric orientation of 3 trajectories around the dome. This semiradial fault system is the most homogeneous and widespread geologic pattern associated with the Tharsis province, which presently is an elevated and irregularly shaped complex of Tharsis Montes and Syria Planum. The fault pattern indicates early regional doming as a unifying characteristic of the province, followed by a wide variety of tectonic elevation changes, erosion, and major volcanic constructions breaking the original simple tructure into its present complex array of subprovinces. In detail the Arcadia faults show a change in trend, from northeast for the older o north for the younger. A plausible mechanism for this rotation of stress trajectories would be an eastward migration with time of the axis of uplift, causing a change in orientation of radial lines at these higher latitudes. The cause for localization of the older fault system of Tempe Fossae is unknown, although the alinement of three younger giant volcanoes of Tharsis southwestward along this line

suggests that the fault system may reflect an extensive zone of deep crustal

Evidence of another Tharsis-related stress system is found in the quadrangle.

The north-northwest-trending mare-type ridges of Lunae Planum are part of a

far-reaching pattern extending in a broad arc through quadrangles to the south.

nterpretation of these ridges as the surface expression of feeder dikes of the associated lavas would indicate a o3 stress orientation normal to these ridges, considerably different from that of the younger fault-related systems. Alternatively, the ridges can be interpreted as compressional features associated with a slight radial spreading of the rising Tharsis province in its early stages. This more attractive interpretation would require only a modest reorientation of the stress system o create the subsequent semiradial fault pattern. Approximate age limits can be set for certain broad topographic features within he Arcadia quadrangle. The pseudo-radial lava-channel system of Alba Patera, which trends strongly northwest and southeast, suggests broad arching along a northeast-trending axis through the volcano during outpouring of its flows. The orthwest border of the Tempe Plateau includes the wide belt of Mareotis Fossae, poorly defined, broad valley, subparallel to the Tempe Fossae fracture system. atures of the present north-south-trending west edge of this plateau south of Mareotis Fossae suggest later modifications of the ancient boundary. This plateau edge contains the roots of large craters similar to those in the intensely cratered upland material, which indicates that it is a deeply eroded scarp of the uplifted plateau and probably a line of anticlinal arching along that edge. The swarm of parallel ridges in this area is then interpreted as the remains of fracture fillings long the axial zone of the arch. The time of arching is poorly dated but appears older than the etched upland material and also older than the adjacent plains terrain of crater density about 3,000 to 5,000 (3.8-3.9 b.y.). Similar or slightly older ages can be assigned to the Kasei Vallis deposits and the cratered plains material that either encroach on or cover the south edge of the plateau, tilted probably at a time of crater density about 5,000 (3.9 b.y.). A broad, subtle upwarp seems to extend northwestward from across the Tempe lateau to the northwest corner of the quadrangle; along this strip the Lunae lanum material and the similarly aged cratered and fractured plains material are exposed, adjacent to younger terrains lapping up onto the structure from the northeast and southwest. The core of this structure is the locus both of large exposures of the intensely cratered upland material in the Tempe Plateau, and of a line of very large old craters on the plains near lat 55°N. The distribution of younger terrains over the core of this anticlinorium, as well as the subparallelism to it of mare-type Lunae Planum ridges, indicate a time of arching similar to or preceeding effusion of the Lunae Planum material, at a crater density of 15,000 o 20,000 (4.1 b.y.). This arch, with its flanking cratered and fractured plains, fractured uplands, and Lunae Planum materials, transects the major boundary between the cratered uplands of Mars and the lower elevation areas of the northern plains; the sub-Mareotis Fossae boundary between intensely cratered and lightly cratered crustal types thus predates the Lunae Planum surface. The first evidences of Tharsis-oriented arching and deformational history begin at crater densities of 15,000 to 20,000 and extend through Alba volcanism of at least

beginning about 4 b.y. ago. REFERENCES CITED Carr, M. H., 1974, Tectonism and volcanism of the Tharsis region of Mars: Journal of Geophysical Research, v. 79, no. 26, p. 3943-3949. 1975, Geologic map of the Tharsis quadrangle of Mars: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-893, scale Gatto, L. W., and Anderson, D. M., 1975, Alaskan thermokarst terrain and possible martian analog: Science, v. 188, no. 4185, p. 255-257. Malin, M. C., 1976, Age of martian channels: Journal of Geophysical Research, May, P. R., 1970, Pattern of Triassic-Jurassic diabase dikes around the north Atlantic in the context of predrift position of the continents: Geological Society of America Bulletin, v. 82, no. 5, p. 1285-1292. Milton, D. J., 1975, Geologic map of the Lunae Palus quadrangle of Mars: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-894, scale Neukum, Gerhard, and Wise, D. U., 1976a, Mars: A standard crater size-frequency 1976b, Mars: A standard crater curve and possible new time scale: Science,

Soderblom, L. A., Kreidler, T. J., and Masursky, Harold, 1973, The latitudinal

distribution of a debris mantle on the martian surface: Journal of Geophysical

U.S. Geological Survey, 1976, Topographic map of Mars: U.S. Geological Survey

Tharsis ridge of Mars: International Colloquium of Planetary Geology,

Wise, D. U., 1975, Faulting and stress trajectories near Alba volcano, northern

Miscellaneous Geologic Investigations Map I-961, scale 1:25,000,000.

University of Rome, Sept. 22-30, 1975, Expanded Abstracts, p. 101-104.

v. 194, no. 4272, p. 1381-1386.

Research, v. 78, no. 20, p. 4117-4122.

1,000. This the Tharsis tectonics extends over much of the planet's history,



